

Energy and centrality dependence of particle production at very low transverse momenta in Au+Au collisions

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Abstract. The PHOBOS experiment at RHIC has the unique capability of measuring particle production at very low transverse momenta. New results on low-transverse momentum invariant yields of π^\pm , K^\pm and $(p + \bar{p})$ in 200 GeV Au+Au collisions are presented as a function of the collision centrality for the 50% most central events. In contrast to the results from d+Au collisions, no m_T scaling is observed in the very low p_T region. The low transverse momentum yields agree with extrapolations from intermediate transverse momentum measurements. For all collision centralities a flattening of the transverse momentum spectra is observed, consistent with a rapid transverse expansion of the system.

The PHOBOS detector at the Relativistic Heavy Ion Collider (RHIC) at Brookhaven National Laboratory has been used to measure low-transverse momentum invariant yields for π^\pm , K^\pm and $(p + \bar{p})$ produced in collisions of gold nuclei at a center-of-mass energy per nucleon pair of 200 GeV (Fig. 1). The analysis is based on a large statistics dataset that allows the data to be split in four different centrality classes 0-6%, 6-15%, 15-30% and 30-50% most central events instead of the one centrality class that was available for the first 200 GeV analysis [1]. For π^\pm , K^\pm and $(p + \bar{p})$ the yields are determined at four different ranges of pseudorapidity and transverse momentum as was done for the analysis at 62.4 GeV center-of-mass energy [2]. Both systematic and statistical errors were calculated separately for each measured yield. The average combined errors vary from 15% to 22% for pions, 17% to 24% for kaons and 22% to 55% for $(p + \bar{p})$. The increase of systematic errors for $(p + \bar{p})$ is related to the small number of reconstructed particles that leads to significant differences between experimental and Monte Carlo $(p + \bar{p})$ spectra.

In Figure 2 the new results are compared with results from the previous Au+Au analysis at 62.4 GeV as a function of centrality defined by the number of participating nucleons. The data for the two first centralities 0-6% and 6-15% are merged to match the centrality classes available at the lower energy. The yields shown in Figure 2 were also averaged over transverse momentum ranges. For both energies a similar centrality dependence is observed for π^\pm , K^\pm and $(p + \bar{p})$.

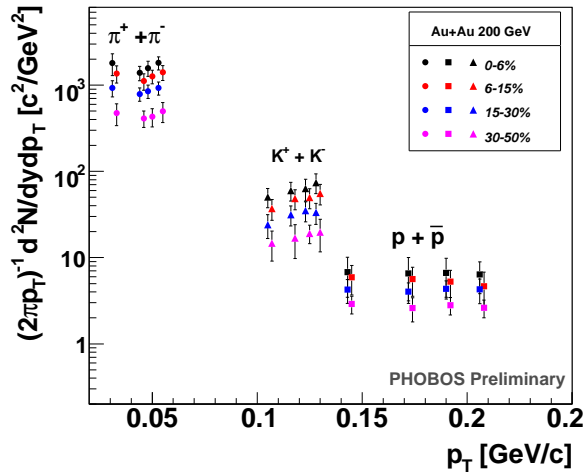


Figure 1: Identified particle spectra at very low p_T near mid-rapidity in Au+Au collisions at $\sqrt{s_{NN}} = 200$ GeV. Combined systematic and statistical errors are shown.

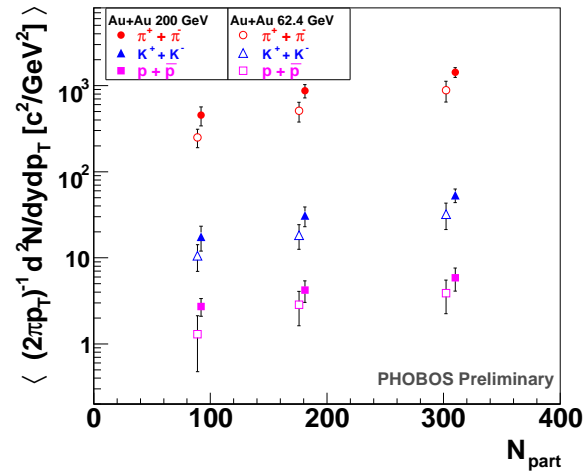


Figure 2: Invariant yields for Au+Au collisions at 200 GeV (solid symbols) and 62.4 GeV (open symbols) as a function of centrality. The yields are averaged over p_T .

It is interesting to compare very low transverse momentum results with the data obtained from the intermediate p_T region. The comparison is performed using data from the PHENIX experiment [4] that has measured positively and negatively charged identified particle spectra in various centrality bins. Because the charge sign cannot be

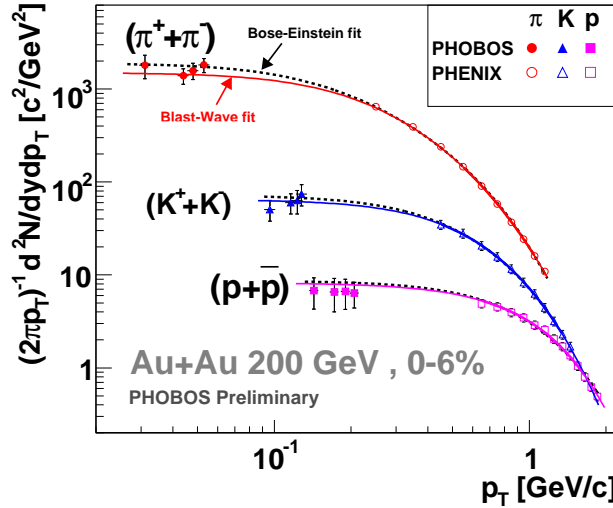


Figure 3: Blast-Wave (solid line) and Bose-Einstein (dotted line) parameterizations fitted over the PHENIX data and extrapolated to the lowest p_T are compared with PHOBOS results.

determined in the analysis of very low p_T particles, we compare only the sum of yields of negative and positive charges. To extrapolate to the lowest p_T regions, Blast-Wave [5] and Bose-Einstein [1] parameterizations are fitted to the PHENIX data (see Fig. 3). The Blast-Wave and Bose-Einstein functions fitted in the intermediate p_T region are then extrapolated to the lowest p_T . For the Blast-Wave parameterization $\beta(r) = \beta_s(r/R)^n$ we assume a source radius $R = 10$ fm and the parameter n is set to 1. The Blast-Wave parameters, transverse velocity β_T and freeze-out temperature T_{fo} , are listed in Table 1.

The Bose-Einstein parameterization, $A [e^{m_T/T} \pm 1]^{-1}$ was fitted to the intermediate p_T region and then extrapolated to low p_T range. Temperature parameters T_π, T_k, T_p are obtained for each particle type (see Table 1). The extrapolation down to low p_T is shown in Fig. 3 and compared with PHOBOS results. We see that in each centrality bin both extrapolations agree well with our measured data. No centrality dependence is observed for either Blast-Wave parameter, T_{fo} or β_T . Similar to the previous low p_T analysis, no anomalous enhancement of invariant pion yield at very low p_T is observed [1]. The next important observation is the flattening of the shape of particle spectra in the very low p_T range. The flattening clearly visible for $(p + \bar{p})$ increases with particle mass and is consistent with a transverse expansion of the strongly-interacting system.

Table 1: Parameters obtained from Blast-Wave and Bose-Einstein fits.

centrality	T_{fo} [MeV]	β_T [c]	T_π [MeV]	T_k [MeV]	T_p [MeV]
0-6%	100 ± 4.0	0.81 ± 0.03	229 ± 5.0	291 ± 11	398 ± 15
6-15%	106 ± 3.3	0.78 ± 0.03	229 ± 5.0	293 ± 11	388 ± 14
15-30%	105 ± 4.4	0.79 ± 0.03	227 ± 5.0	288 ± 10	370 ± 13
30-50%	103 ± 3.8	0.78 ± 0.03	209 ± 4.8	278 ± 10	333 ± 11

We have also investigated the m_T spectra ($m_T = \sqrt{p_T^2 + m_0^2}$). Figure 4 (upper plot) shows the m_T spectra in four centrality classes as well as the inverse local slope parameter T_{loc} (bottom plot) calculated in order to more easily show differences in the slope of the particle spectra. In Au+Au collisions no m_T scaling [6] is observed in the very low p_T

region, while d+Au data [3] at $\sqrt{s_{NN}} = 200$ GeV (Fig. 5) exhibit m_T scaling over the full p_T range.

HIJING [7] and the Single Freeze-Out (Therminator) [8] model calculations are compared with low p_T data for Au+Au collisions at $\sqrt{s_{NN}} = 200$ GeV. The model predictions were obtained for the most central bin separately for π^\pm , K^\pm and $(p + \bar{p})$ (Fig. 6). The comparison shows that both models well describe pion spectra. For heavier particles the single freeze-out model agrees very well with low p_T results. In contrast, the HIJING model overestimates proton and antiproton yields and the same tendency, although weaker, is seen in the kaon spectra.

In conclusion, identified particle spectra in Au+Au collisions at $\sqrt{s_{NN}} = 200$ GeV have been measured at very low p_T in four centrality bins. Blast-Wave and Bose-Einstein parameterizations well describe the data at very low and intermediate p_T . At the very low transverse momenta spectra, we observe flattening which increases with particle mass consistent with rapid transverse expansion of the system. In Au+Au collisions no m_T scaling is observed in contrast to results from d+Au collisions at $\sqrt{s_{NN}} = 200$ GeV. The Single Freeze-Out model is consistent with the presented results.

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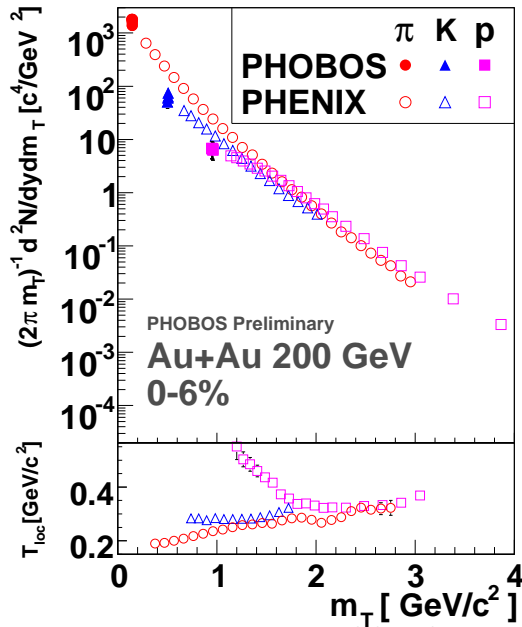


Figure 4: m_T spectra and local inverse slope of $(\pi^+ + \pi^-)$, $(K^+ + K^-)$ and $(p + \bar{p})$ at low and intermediate p_T measured in Au+Au at $\sqrt{s_{NN}} = 200$ GeV.

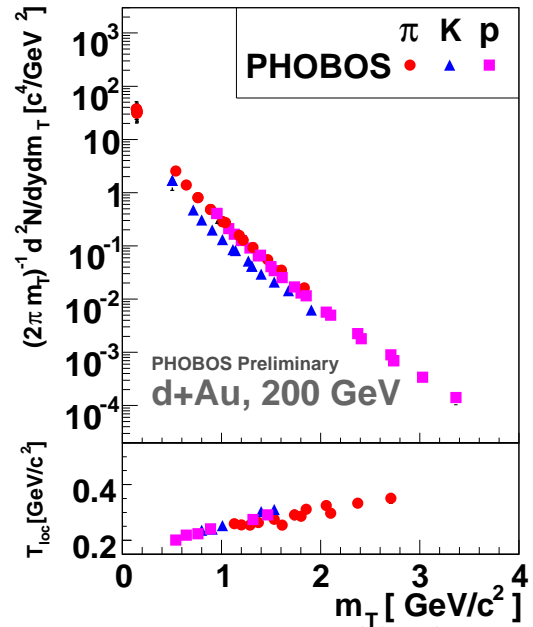


Figure 5: m_T spectra and local inverse slope of $(\pi^+ + \pi^-)$, $(K^+ + K^-)$ and $(p + \bar{p})$ at low and intermediate p_T measured in d+Au at $\sqrt{s_{NN}} = 200$ GeV.

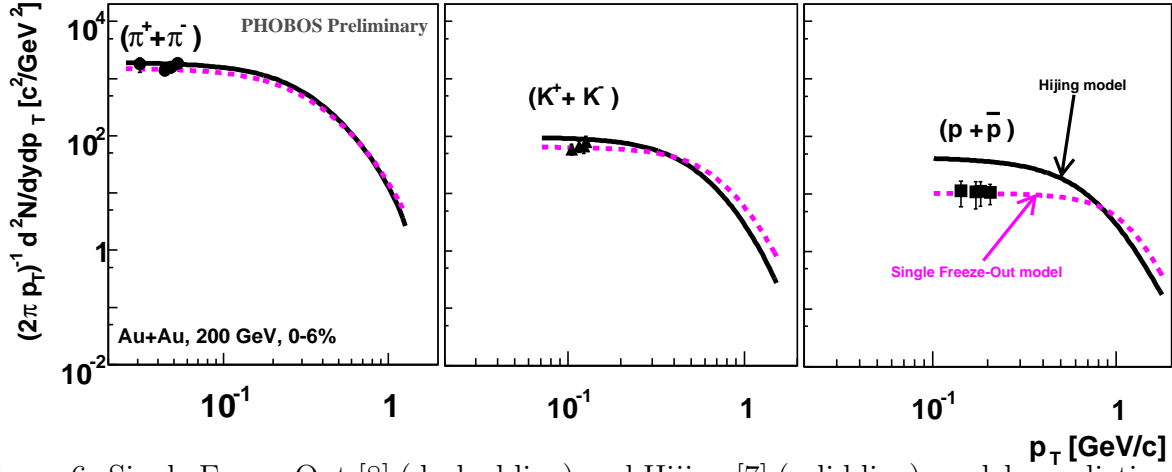


Figure 6: Single Freeze-Out [8] (dashed line) and Hijing [7] (solid line) models predictions compared with very low p_T data.

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